Automatic vs. Human Detection of Bipolar Magnetic Regions: Using the Best of Both Worlds

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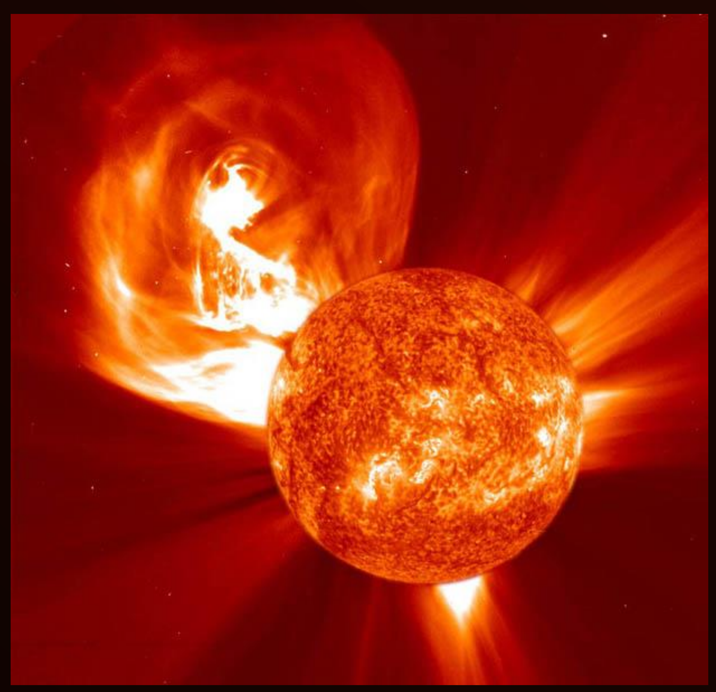
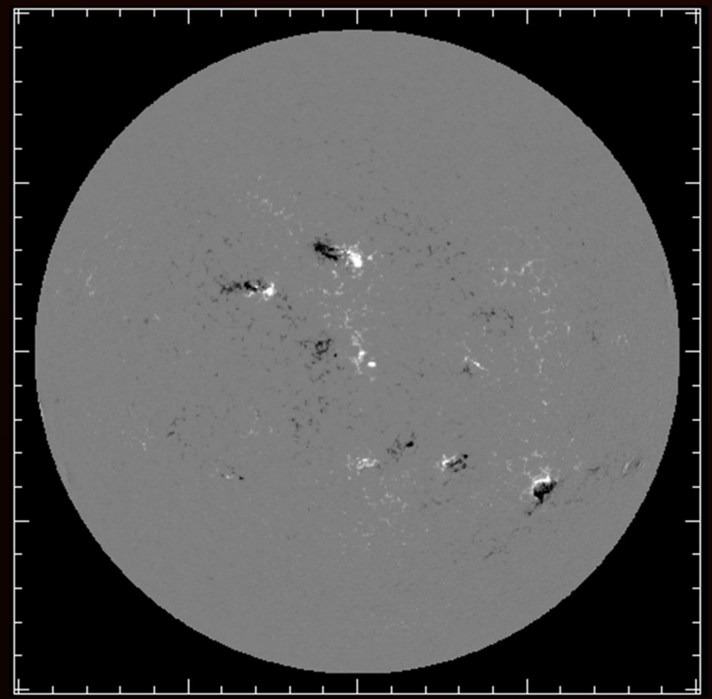
The Solar Cycle



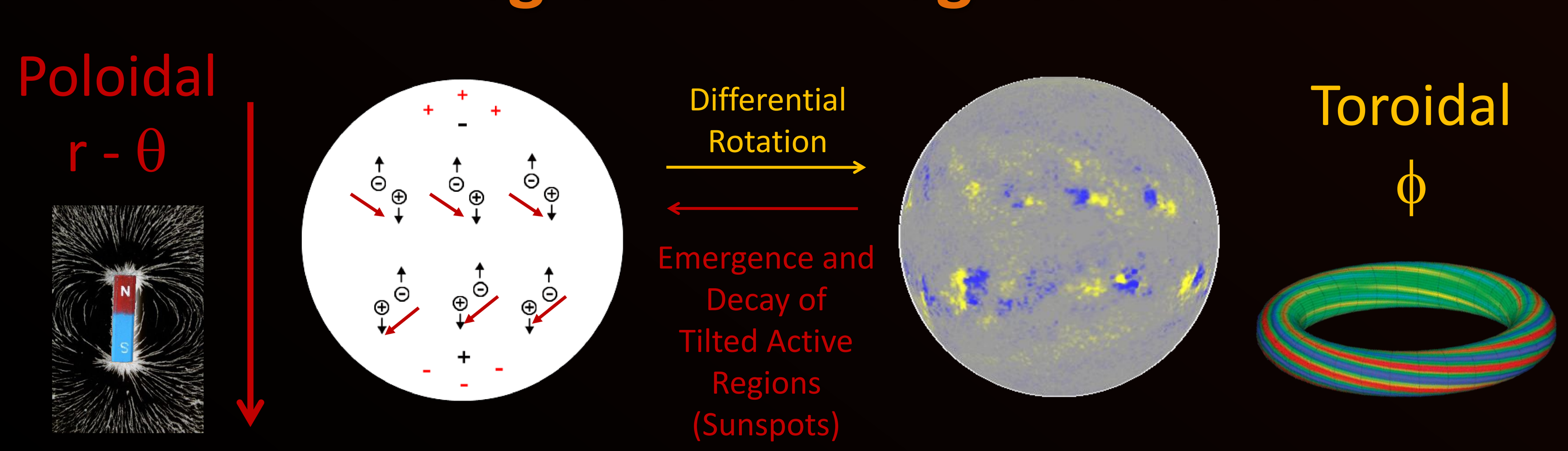
- Sun goes through periods of high and low activity on a roughly 22-year cycle
- Heats upper atmosphere of Earth
- Increased/Decreased number of solar flares and coronal mass ejections
- Possible effect on Earth's climate

Bipolar Magnetic Regions (AKA Active Regions)

- Pairs of positive and negative magnetic field that emerge from Sun
- Cause sunspots
- We used SOHO/MDI data from 1996 to 2011. This is an example of an MDI magnetogram

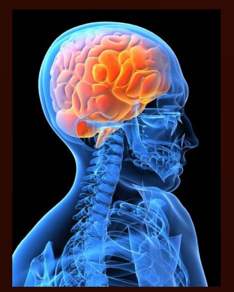


Active Regions and Magnetic Fields



The Sun's magnetic field starts almost entirely poloidal at the beginning of a cycle, but gains a toroidal component due to differential rotation in the Sun. The toroidal component causes the formation of active regions which contribute to the poloidal field, setting up the field for the next cycle.

The collective action of the Active Regions drives the solar cycle, so we want to understand their statistical properties.

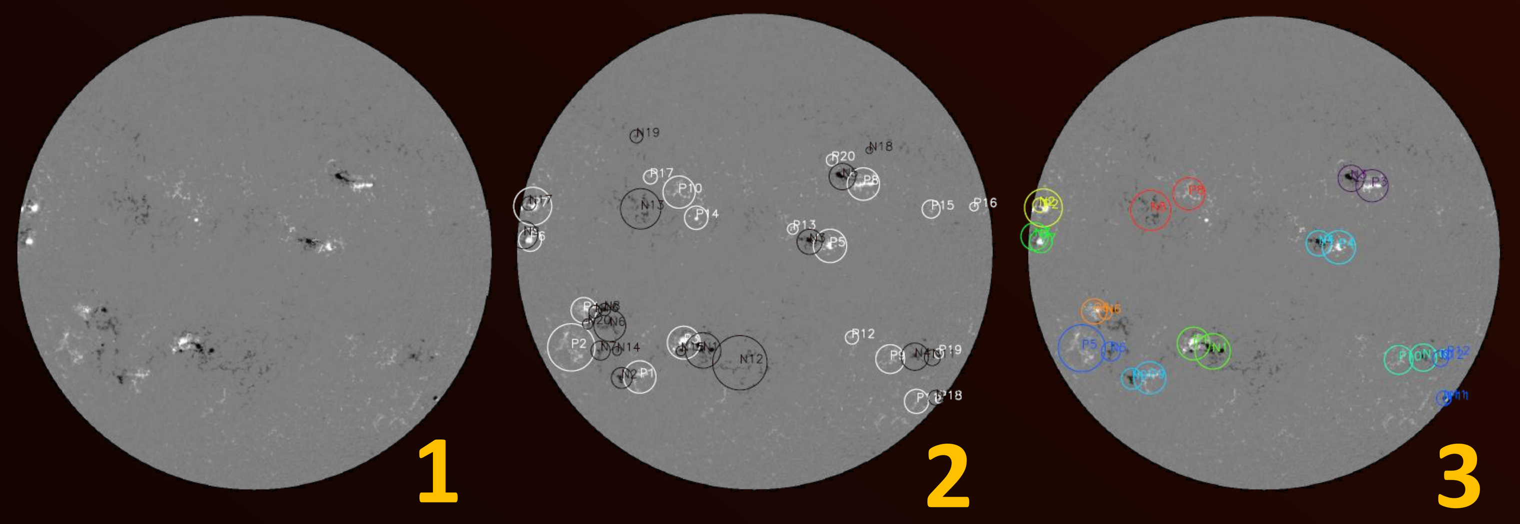


Project

- We used SOHO/MDI data from 1996 to 2011 to find and track active regions
- Computer detects positive/negative regions and performs initial pairing and tracking
- Human reviews results and makes corrections
- This combines the pattern-finding skills of a human with the consistency of a computer

Ultimate Goal: Create a database of active regions for the study of the solar cycle

Automatic Detection of Active Regions



The BARD (Bipolar Active Region Detection) code is used to detect active regions in SOHO/MDI magnetograms, and then track their movement across the visible face of the Sun. The code works in three steps:

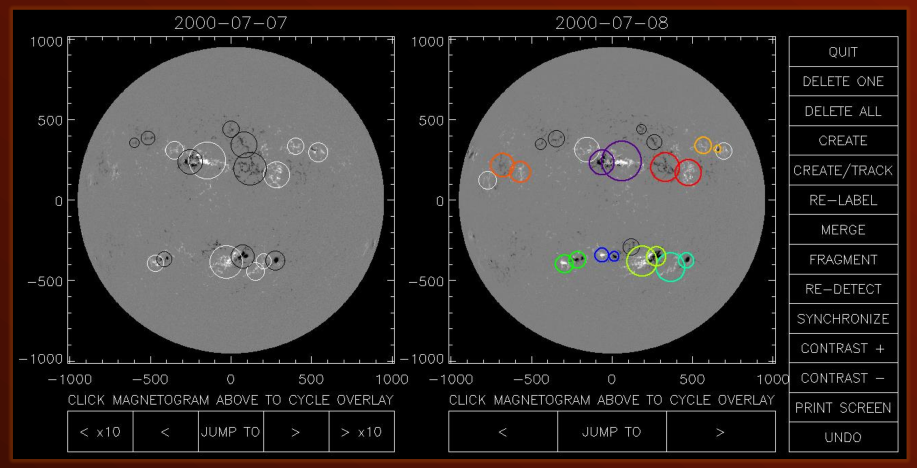
1. Detection of positive and negative regions separately
2. Aggregation into active regions based on size, flux and distance
3. Tracking of active regions across magnetograms

A variety of parameters in the code are used to govern this process. A parameter-space search was performed prior to processing the dataset in order to maximize the computer's ability to detect and track active regions before human intervention.

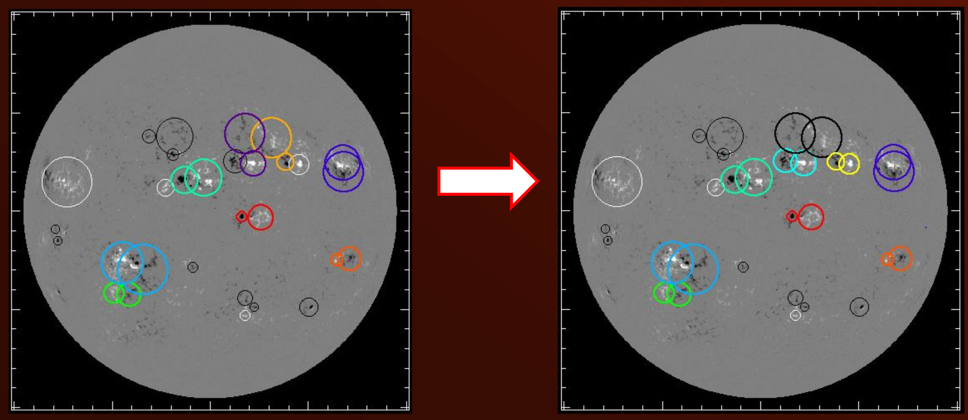
Image Sources: pitt.edu, solar.physics.montana.edu, https://solarsystem.nasa.gov/multimedia/gallery/PIA03149.jpg

Human Interface

We developed an interface to allow a human observer to supervise the automatic detections process and correct any errors.



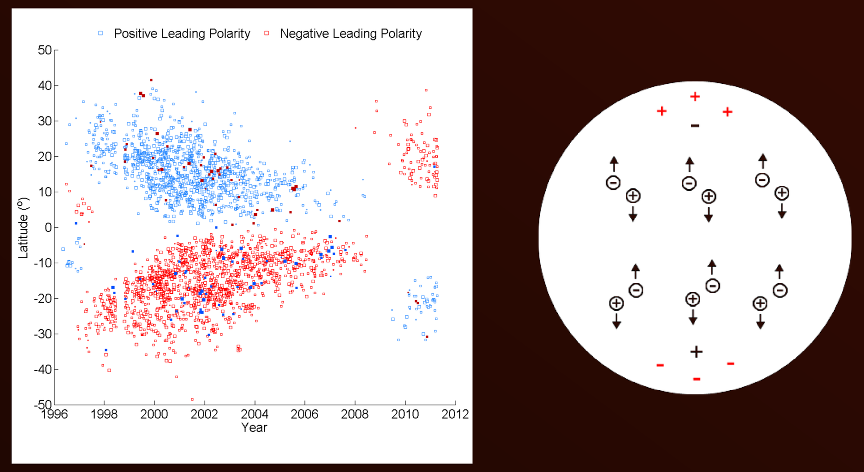
Sample computer error



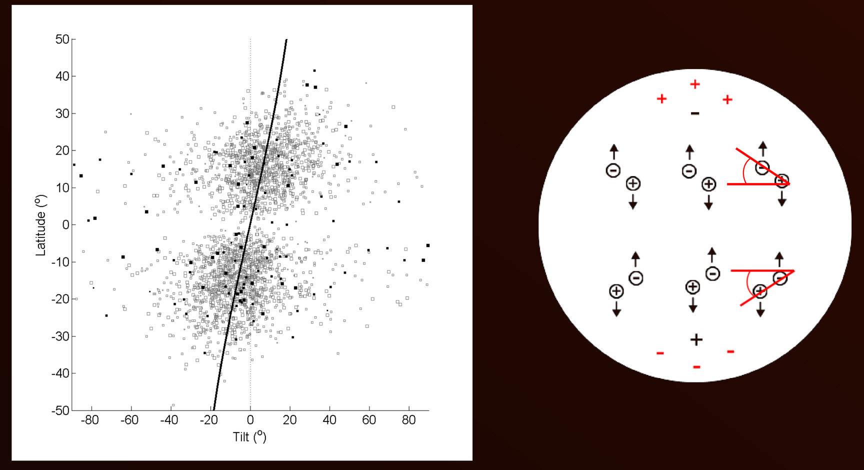
Improved result

This gives our catalog an unprecedented level of consistency and quality, making it ideal for solar cycle studies.

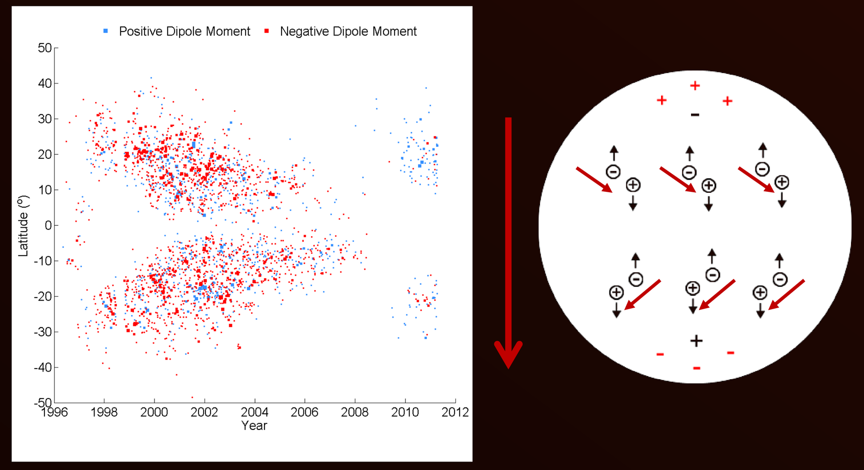
Some Initial Results from Catalog



This butterfly diagram illustrates Hale's polarity orientation law (one polarity leads in each hemisphere). Only 5% of active regions in our catalog violate it.



Joy's active region tilt law says that the average tilt of active regions increases with latitude.



This butterfly diagram shows the dipolar contributions of the active regions. Some have a conflicting contribution.